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TITLE: A HIGH CURRENT PULSER FOR EXP. 225, "NEUTRINO ELECTRON ELASTIC SCATTERING"

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A HIGH CURRENT PULSER FOR EXPERIMENT #225, "NEUTRINO ELECTRON ELASTIC SCATTERING

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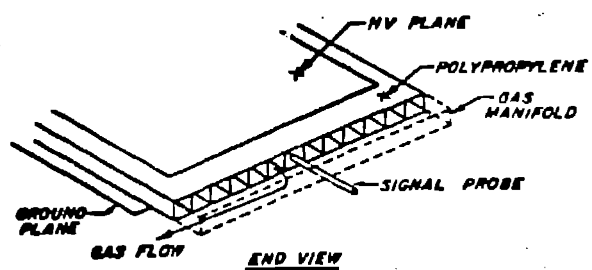
Abstract

With the advent of low-cost honeycomb extrusions of polypropylene sheets, flash chambers have become very attractive for large nuclear particle detector arrays. This has brought about the need for a pulse power system that will provide high peak currents and low levels of spurious radiation. Each module of 10 flash chambers will require a peak current of 70 KA with a rise time (τ_r) of < 50 ns, giving a maximum rate of current rise di/dt of 400 KA/μs. The pulser output must develop 7 KV across a load of 0.36 Ω with a pulse width of 500 ns. The repetition rate will be one per second. This paper describes the development of such a system and the impact of the physical limitations of present component technology on lifetime and pulse fidelity.

Introduction

In an article published in Nuclear Instruments and Methods, Volume 158, page 289 (1979), we discussed a system which allows rapid data collection from particle detectors known as "Flash Chambers." A flash chamber consists of a noble gas mixture confined between two conducting plates in a dielectric container. The conducting plates are pulsed to a high voltage level in coincidence with the passing of a charged particle and a plasma is then formed in the dielectric container. At this point the data may be extracted optically or in some cases electrically. Until recently, data collection from flash chambers was a slow and tedious process because a photographic method was employed. Complexity of construction and high cost have also curtailed the use of these novel detectors, but with the advent now of low cost honeycomb extrusions of polypropylene sheets, flash chambers (Fig. 1) have become very attractive components for large particle detector arrays. The flash chamber readout system under development will output data at a rate of 2.5 x 10^4 bits per interrogation. The period of one interrogation is less than 0.01 s as compared to the previous optical system outputs of several hundred bits requiring seconds or minutes to accumulate. It is clear that this new readout method will be of great value when fully developed. At this point, however, the system is dependent on substantial technology base developments in the high-voltage pulse power driver.



FLASH CHAMBER CONSTRUCTION

Figure 1

Figure 2 shows a simplified, overall block diagram of our instrumentation system. In this system the flash chamber readout, the high voltage pulser and the voltage monitors are the major areas of development. The high voltage pulser is of main concern at this point and is the focal point of this report. This pulser can be divided down into four separate areas: the load, energy storage, load to pulser interface, and the switch. These areas will be

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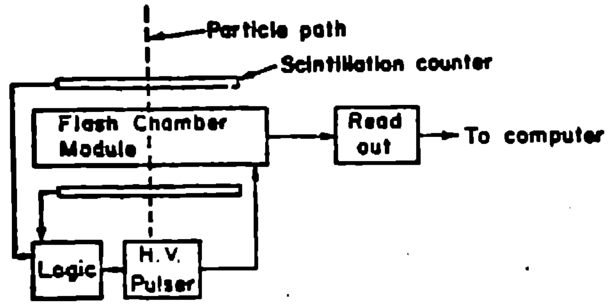


EXPERIMENTAL CONFIGURATION

Figure 2

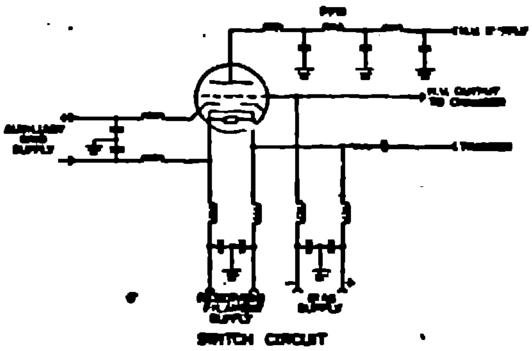


Figure 3

discussed in this order.

The Load

The flash chambers for this system are 3-1/2 m by 3-1/2 m with a thickness of 5 mm, and are clad on both sides with 0.05 mm of aluminum foil, forming a parallel plate capacitor with a capacity of 20 nF. Since these chambers have dimensions comparable to the pulse rise and fall times, they cannot be treated with conventional transmission line theory, and are being analyzed more as a lumped capacitive element than a true transmission line. However, in order to have a point of reference the impedance of a chamber was measured and found to be ≈5 Ω, and the transit time was measured to be 10 ns. The above parameters constitute the predominant characteristics of the flash chamber as an electrical load. In the planned experiment there will be 450 flash chambers. Each pulser will have to drive a module consisting of 10 chambers.

Energy Storage

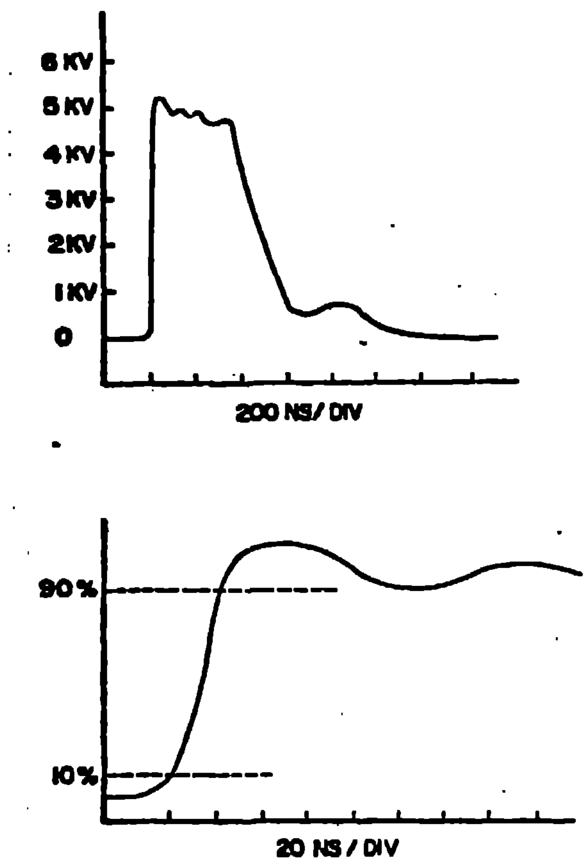
For proper operation and peak efficiency the flash chambers require a rectangular pulse, with a duration of 500 ns from a source with an impedance of 5 Ω, requiring a pulse-forming network (PFN) to meet these needs. Initially a Type C PFN was used, however, difficulty with saturating toroid inductors and poor pulse fidelity on the falling edge precipitated a change to the Type B presently in use (Fig. 3). In the first stages of PFN design, computer modeling was used to arrive at a prototype design. This prototype PFN was then tested under load conditions and adjusted to compensate for distributed parameters not included in the modeling program. Since high peak currents and low inductance are required, in conjunction with a life time of 10^7 shots (MTBF, 90% confidence level), capacitor selection is non-trivial. At present capacitors manufactured by Axel, Sprauge and Murata are under test. The mica capacitors from Axel Type MP 5AW have an equivalent series resistance (ESR) of 2.10 Ω for a 6.5 nF unit with an estimated life of 10^{10} shots. The Murata DHS series capacitors have an ESR of 1.90 Ω and a guaranteed shot life of 10^4. The Sprauge Type 720C has an ESR of 6.4 Ω and an estimated shot life of 10^6. With the above lifetime data the emphasis has been placed upon the development of PFN utilizing the Axel mica capacitors.

Load to Pulser Interface

In transmitting the power from the switch and PFN assembly to the chambers, the characteristics of both strip line and coaxial transmission lines have been assessed. Coaxial lines have given the best results so far, but have not met design rise-time requirements. Coaxial lines worked well into a resistive load (Fig. 4), however, when the load of the chambers was put on to a pulser output, the shock oscillations and impedance mismatch caused a severe degradation in pulse fidelity and rise time (Fig. 5). Further development of both transmission lines is currently under way.

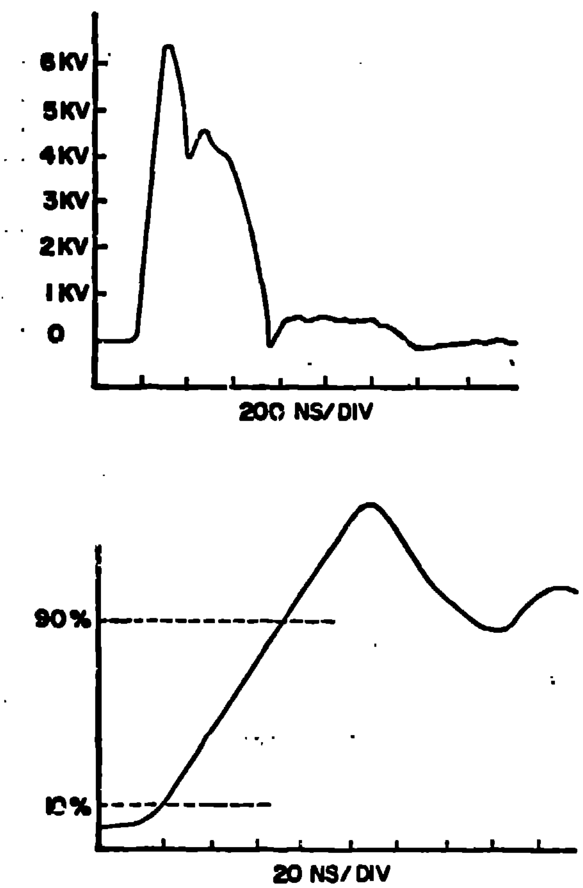
The Switch

After an extensive market study and vendor interactions, an EG&G thyratron was chosen for initial prototyping. The choice of a thyratron over a spark gap was based on the low spurious noise requirement and a > 10^7 shot life. The EG&G HY-13 is now being tested and at this point test results indicate that



PULSE INTO 0.9 Ω LOAD

Figure 4



PULSE ON CHAMBER

Figure 5

this switch may well be just adequate to the task. In order to improve the switch performance and so reduce even further the total number of switches required, EG&G is developing a new grounded grid thyratron, the HY-1313 for our specific application and we are now preparing a test geometry for this tube. Figure 3 shows the HY-13 circuit layout. The PFN, switch loop and electrical PFN placement are the main layout changes foreseen. These changes will reduce τ_r and improve the physical layout of the pulser. To date we have tested the HY-13 to a peak current of 5500 amperes into a 0.9 Ω load and were able to obtain a τ_r of 10 ns. This is to be compared to the goal of 20 KA into a 0.4 Ω with a τ_r of < 50 ns, meaning a di/dt of 400 KA/μs.

Conclusion

Considering shot life and ESR, the Axel capacitors are being used for further testing of the PFN. The HY-13 at the present stage of testing has successfully driven 40% of the load and at this time looks acceptable. EG&G is manufacturing a new tube (HY-1313) which should improve the performance of the pulser.

In conclusion there does not appear to be a problem with the PFN or switch. The main area of concern is the interface between the switch and the load and the problem is how to transmit large currents with fast rise time into a capacitive load. This aspect of the system design is currently under detailed study.

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